B+K Audio Frequency Spectrometer

Description

General 5

Input Amplifier 6

Input Circuit 6

Calibration Voltage 6

Amplifier Section 8

Hum Elimination, Stabilization, Linear Distortion and Microphonic Reduction 8

Filters 8

⅓ Octave Filters 8

¼ Octave Filters 13

Weighting Networks 14

Selection of the Filters 16

Remote Control 16

Extension Filters 17

Output Amplifier 17

Input Circuit 17

Sensitivity Adjustment 18

Output 18

Output Voltage 18

Rectifier and Meter Circuit 18

R.M.S. Measurements 18

Arithmetical Average Measurements 19

Peak Measurements 19

Damping and Graduation of Meter 21

Overall Performance of the Instrument 21

Signal-to-Noise Ratio 21

Overloading 21

Frequency and Phase Response 23

Power Supply 23

Polarization Voltage 23

Fuse and Selection to Correct Power Voltage 24

Description

General.

The Audio Frequency Spectrometer Type 2111 is primarily designed for analysis in the field of acoustics, electro-acoustics, vibrations and electronics in the frequency range 35—35000 c/s.

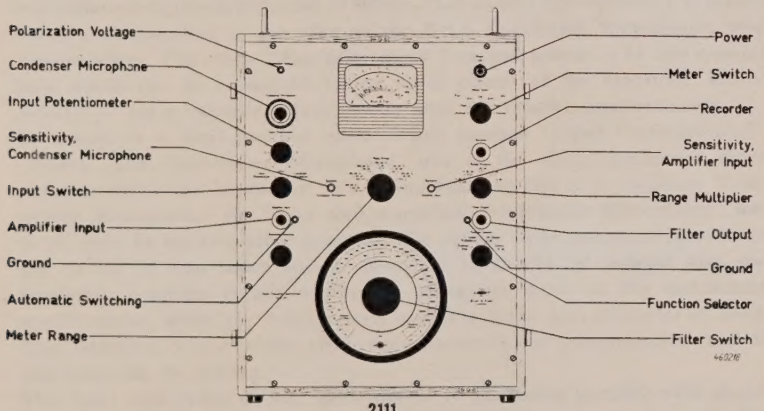


Fig. 1. Frontal view of Spectrometer Type 2111 with control knob identification.

It consists basically of an input amplifier, a filter system of band-pass filters and weighting networks, and an output amplifier as shown in the block diagram Fig. 2.

The bandwith of the filters (except for the weighting networks) is ⅓ or 1/1 octave, which makes the instrument well-suited for the frequency analysis of noise and vibration signals, as well as for selective measurements. These filters may be selected manually or electro-mechanically. The electro-mechanical switching of the filters is performed by a built-in electro-magnetic device, which can be controlled externally via a contact, or a contact in series with a d. c. supply.

By controlling the switching from a B & K Level Recorder, i. e. Type 2305, it is possible to automatically record spectrograms on preprinted, frequency calibrated recording paper.

The weighting networks are designed to meet the specifications laid down by the tentative international standards for Precision Sound Level Meters.*) When switched to "Lin. 2—35ooo c/s" the frequency characteristic of the Spectrometer is linear to within ± o.3 db in the range 5—20ooo c/s and to within ± o.5 db from 2 c/s to 35ooo c/s.
The indicating instrument is equipped with three different rectifier circuits which enable the true r.m.s., the arithmetical average and half peak-to-peak value of the signal to be measured.
The power supply contains the necessary rectifiers for operating the amplifiers, as well as for operating the B & K Condenser Microphones or a Vibration Pick-up Preamplifier.

Input Amplifier.

Input Circuit. The input amplifier consists of three stages. It is provided with two different input sockets, one of which ("Condenser Microphone") is seven-poled, corresponding to the plug on the B & K Condenser Microphones and Preamplifiers. The other ("Amplifier Input") accommodates a 14 mm coaxial jack which can be connected to the input circuit of the amplifier, either directly or via a variable potentiometer used for relative measurements.
By means of a three-position input switch marked "Input Potentiometer", "Direct", and "Condenser Microphone" one of the above mentioned three input facilities can be chosen. When the input switch is in position "Condenser Microphone" the input socket marked "Condenser Microphone" has to be used. In the two other positions the voltage to be measured should be fed to the 14 mm input socket. However, it should be noticed that the frequency response is not within the tolerances given in the instrument specifications, when the continuously variable input potentiometer is used. The deviation is due to the stray capacitance of the potentiometer and is dependent on the setting.
The input impedance of the Spectrometer is 2.2 Mohm parallel with 30 pF when the "Input Switch" is set to "Direct"**). From this input switch the signal voltage is fed to a voltage divider, which is operated by the knob marked "Meter Range" on the front panel and contains five steps of 20 db. The different positions are indicated by the values "10 mV" to "1ooo V", "— 60 db" to "+ 40 db", and "60 db S.L." to "160 db S.L.".

Calibration Voltage. A further position "Ref." serves to connect a calibration voltage to the amplifier input, which is a square wave type signal, with the repetition frequency equal to that of the mains. By means of this voltage the gain of the amplifiers can be calibrated. The correct calibration is obtained

*) As discussed at the International Electrotechnical Commission (I.E.C.) TC 29 in Rapallo 1960.

**) If a very high input impedance is required, this can be obtained by connecting one of the B & K Cathode Followers 2612, 2613, 2614 or 2615.

when the deflection of the meter pointer is adjusted to coincide with the red mark of the meter scale.

For the reason given below the calibration adjustment to the red mark should be carried out with the "Meter Switch" in position "R.M.S." and the "Function Selector" switch set to "2—35000 c/s Linear". With the "Function Selector" switch in this position, the average reading of the reference signal coincides with the red mark on the scale, while the peak value will be indicated by a 0.5—1 db greater deflection. When the "Function Selector" switch is in position "⅓ Octave" and the "Filter Switch" on "Lin." the R.M.S. calibration will still show a correct value. The average and peak reading however, will now deviate from same. A deviation of up to 4 db may be expected when the "Meter Switch" is switched to "Peak".

The deviations between the peak, average and R.M.S. readings described here, are mainly caused by phase distortion in the amplifier. This will be noticeable on peak measuring of complex signals, the fundamental frequency of which is just above the lower limiting frequency of the amplifier. For this reason, the above mentioned deviations in reference voltage readings will be smaller when the apparatus is supplied from a power line with a frequency higher than 50 c/s.

The reference voltage, which is based on the voltage stabilizing effect of a zener diode, will vary less than 0.3 % for a 10 % variation in the mains voltage.

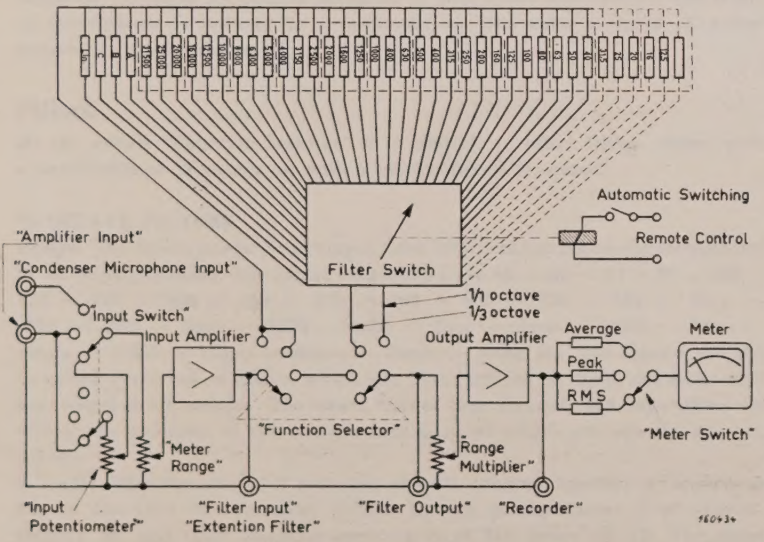


Fig. 2. Block diagram of Spectrometer.

Amplifier Section. The first two stages of the amplifier consist of resistance-capacitance coupled triodes, while the third stage is built as a cathode follower. A great amount of negative feedback is introduced to stabilize the amplifier and ensures a low source impedance (approximately 10 Ω) to be coupled to the filter system.
A terminal on the rear side of the instrument marked "Filter Input - Extension Filter" parallels the filter section input, thereby enabling either the input amplifier to be used separately, or a B & K Extension Filter Set Type 1619 to be connected. The Extension Filter Set extends the frequency range of selective measurements down to 14 c/s.

Hum Elimination, Stabilization, Linear Distortion and Microphonic Reduction. The hum level of the instrument is extremely low, due to the design and high quality of the amplifying circuits. The level is less than 2 μV, with reference to the grid of the first tube in the preamplifier, this being achieved by heating the filament of the first tube in each of the two amplifying sections by means of a DC supply from a rectifier, stabilized by zener diodes. This stabilizing effect ensures the stable sensitivity of the amplifier and makes the influence of normal variations in mains voltage practically negligible. Apart from the above, the harmonic distortion produced, is less than one part in a thousand owing to the heavy negative feedback in the amplifier portions. By careful selection of tube types and circuits the effect of microphony is reduced to a minimum, so that even a signal of a few microvolts can be measured.

Filters.

By the switch "Function Selector" it is possible to select filters, either with a bandwidth of 1/3 octave, or with a bandwidth of 1/1 octave.

1/3 OCTAVE FILTERS

Design. The Spectrometer is equipped with 30 filters having center frequencies of 1/3 octave distance. The center frequencies are 40 — 50 — 63 — 80 — 100 — 125 — 160 — 200 — 250 — 315 — 400 — 500 — 630 — 800 — 1ooo — 1250 — 1600 — 2ooo — 2500 — 3150 — 4ooo — 5ooo — 6300 — 8ooo — 10ooo — 12500 — 16ooo — 20ooo — 25ooo — 31500 c/s. The figures are the so-called preferred numbers which are standardized in most countries and are rounded-off values. The exact values are figures, the logarithms of which are multiples of o.1, i.e. the mantissae of which are exactly o.1, o.2, o.3 etc.
A single filter consists of 3 resonant circuits coupled together as shown in Fig. 3. The first two resonant circuits have a quality factor Q of approximately 10, and their coupling factor k is of the order of o.2. The third resonant circuit has a Q of approximately 5 and is coupled loosely to the two first circuits (k = o.05 approx.).

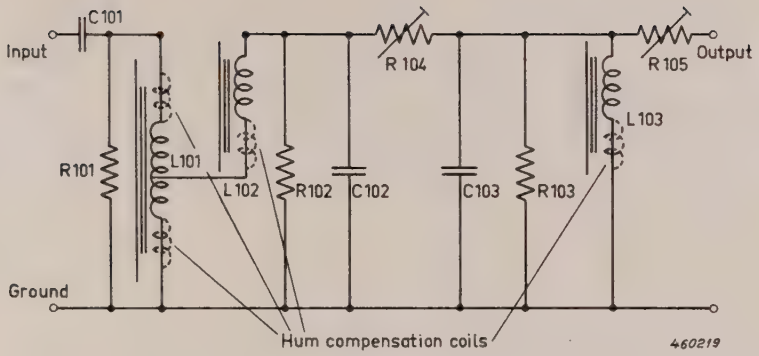


Fig. 3. Schematic diagram of single ⅓ octave filter unit.

The first two circuits will give rise to a two-topped frequency response, as shown in Fig. 4 left, while the third gives a single top which raises the valley between the two tops, so that a resultant curve as shown in Fig. 4 right is obtained, having a relatively flat band-pass and steep sides. Because the quality factor is dependent on the frequency, the two tops will not have the same height. To obtain the desired band-pass, the third resonant frequency must therefore be placed unsymmetrically, and the resultant response curve will have two humps, a broad one and a narrow one.

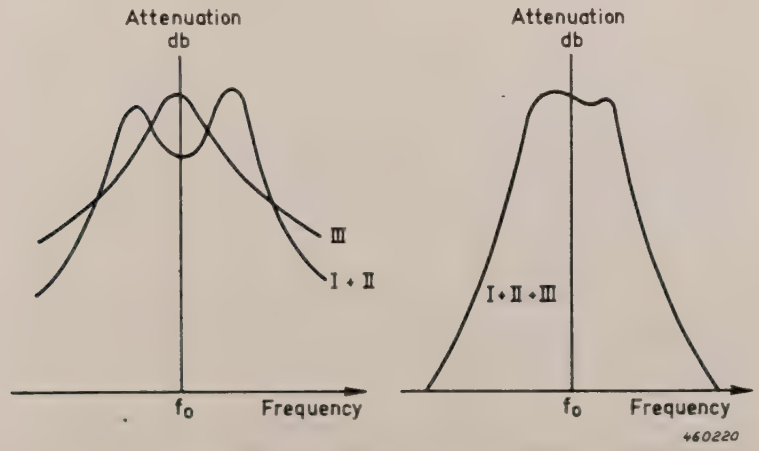


Fig. 4. Frequency characteristics showing function of filter unit.

The input impedance response of all the filters, will be a wave-shaped curve, varying between approximately 500 ohms and 2000 ohms, so that the impedance is high at the center frequencies and low at the band limits. See Fig. 5. The input voltage will therefore also vary up and down if the output impedance of the preamplifier is not made low. In the Spectrometer an output impedance of approximately 10 ohms has been obtained. The voltage across the filters will thus only vary approximately 2 %.

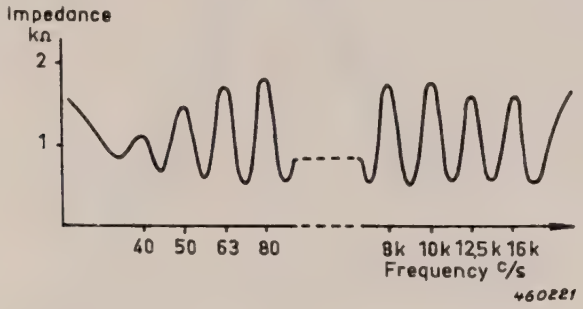


Fig. 5. Variation in input impedance of filter section.

To keep the transients in the filters to a minimum all the filter inputs are coupled in parallel. Furthermore, the filters are pre-loaded, and the change in load—when the "Filter Switch" connects the output amplifier to the different filters—is thus negligible.

Frequency Response. The frequency response of a filter is flat to within ± ½ db over approx. ¼ octave. At the band limits, i.e. ⅙ octave from the center frequency, the attenuation is approx. 3 db, normally a little lower. See Fig. 6. However, due to the rather steep slope of the filter curves at these points, the frequency characteristics of two neighbouring filters cannot be expected to intersect exactly at the 3 db point. This is easy to understand, because a displacing of the center frequencies of the two filters by only 1 % in opposite directions, will cause the intersection to take place at a point 1.7 db higher or lower than the 3 db point. If the width of one filter curve is changed by 1 %, the point of intersection is changed by 0.2 db.
The attenuation approximately at ± ⅓ octave from the center frequency is 20 db, and at ± 1 octave 52 db. It has been impossible to obtain sufficiently high quality factors for the coils at some frequencies below 160 c/s, without lowering the stability or making the filters bigger and heavier. The filter curves will therefore not be of the same quality at these frequencies, which can be seen from Figs. 6 and 7, as there will be only one top, and the "flat" part is about ⅛ octave wide. The attenuation is up to 4 db at the band

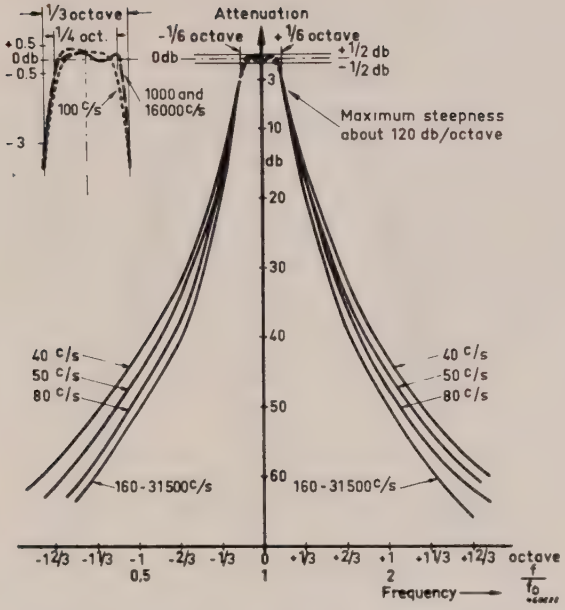


Fig. 6. Detailed ⅓ Octave Filter characteristics.

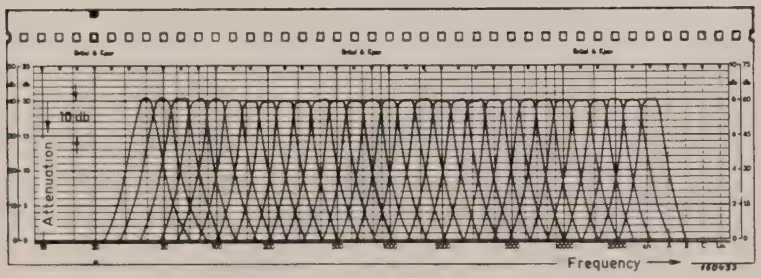


Fig. 7. Frequency characteristics of ⅓ Octave Filters.

limits, from 14 to 20 db at ± ⅓ octave, and from 42 to 50 db at 1 octave away from the center frequency.

Phase Response. Due to the nature of the filters they will cause a phase distortion, which is shown in Fig. 8 together with the amplitude response of the filter top. The hatched area indicates the limits within which the different filter curves for one apparatus are expected to lie.

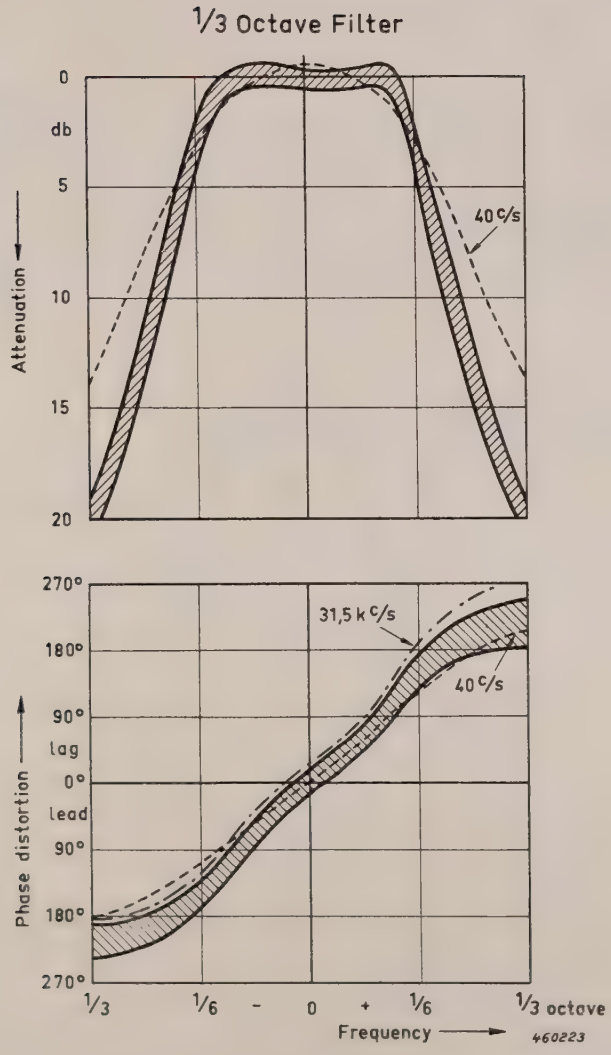


Fig. 8. Phase response curve of ⅓ Octave Filters.

Hum Compensation. To reduce the induction of hum, in the low frequency filters, occuring from magnetic fields created by nearby mains, transformers, or electrical machinery, the filters are provided with hum compensation coils as seen in Fig. 3. By this means a very low hum level is obtained.

1/1 OCTAVE FILTERS

Design. The 1/1 octave filters are obtained by combining three 1/3 octave filters internally, thus the center frequencies are: 50 — 100 — 200 — 400 — 800 — 1600 — 3150 — 6300 — 12500 — 25000 c/s.

Due to the circuit used for connecting three 1/3 octave filters to a 1/1 octave filter a certain voltage drop is unavoidable. This voltage drop is made equal to 10 db, which should be taken into account during measurements. The "Function Selector" switch is therefore in position "Octave" also marked "— 10 db".

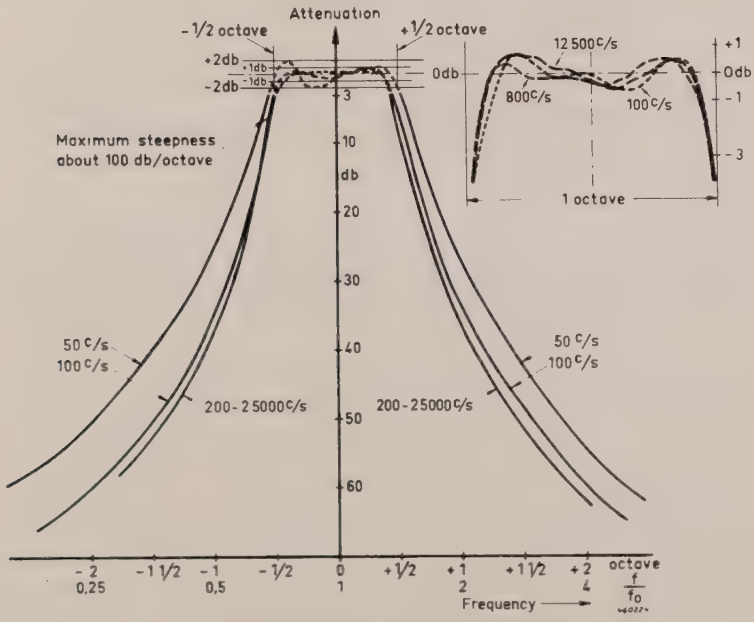


Fig. 9. Detailed 1/1 Octave Filter characteristics.

Frequency Response. The filters are adjusted so that the deviations in the band-pass between peaks and valleys are within ± 1 db, for the lowest octaves within ± 2 db. At the band limits, i.e. ± ½ octave from the center

frequency, the attenuation is approximately 3 db, vide Figs. 9 and 10. The attenuation at ± 1 octave is approximately 35 db, being somewhat less for the very low frequency filters.

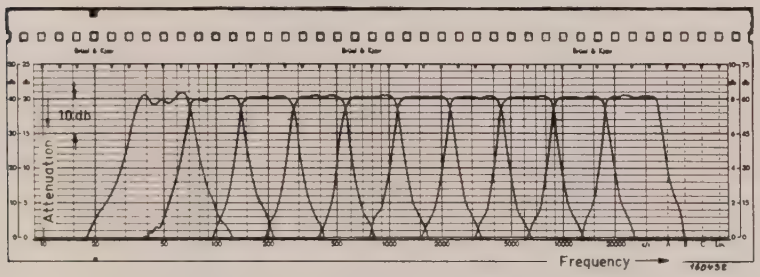


Fig. 10. Frequency characteristics of ⅓ Octave Filters.

Phase Response. The phase response curves of the octave filters are shown in Fig. 11, together with the amplitude response of the filter top. The curves for the different filters are expected to lie within the hatched area.

Weighting Networks.

The networks are arranged as shown in Fig. 12 and the frequency response satisfies the proposed international standards (Rapallo, April 1960) for Precision Sound Level Meters, vide Fig. 13 and table below.

Frequency c/s	10	20	40	80	160	315	630	1000	2000	4000	8000	12500	20000
Curve A	—70.5	—50.4	—34.5	—22.3	—13.2	—6.5	—1.9	Ref.	+1.2	+1.0	—1.1	—4.2	—9.2
Curve B	—38.5	—24.4	—14.2	—7.4	—3.0	—0.9	—0.1	Ref.	—0.2	—0.8	—3.0	—6.0	—11.0
Curve C	—14.5	—6.3	—2.0	—0.5	—0.1	0	0	Ref.	—0.2	—0.8	—3.0	—6.0	—11.1
Tolerance	+5	+5	+3	+2	+2	+2	+2	+1	+2	+3	+4	+5	+5
Ordinary Sound Level Meters IEC standards	—∞	—∞	—3	—2	—2	—2	—2	—1	—2	—3	—4	—10	—∞
Tolerance	+5	+5	+3	+2	+1	+1	+1	0	+1	+1.5	+2	+3	+3
Precision Sound Level Meters Tentative IEC standards	—∞	—5	—3	—2	—1	—1	—1	0	—1	—1.5	—2	—3	—6

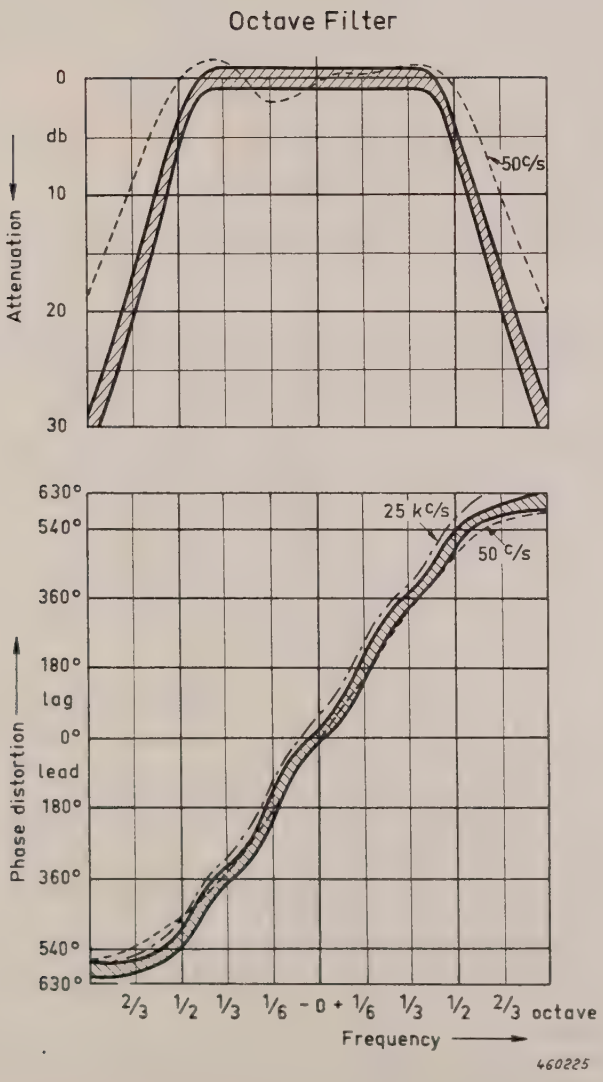


Fig. 11. Phase response curve of ⅓ Octave Filters.

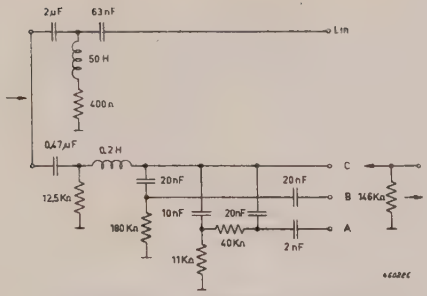


Fig. 12. Schematic diagram of Weighting Networks for sound level measurements.

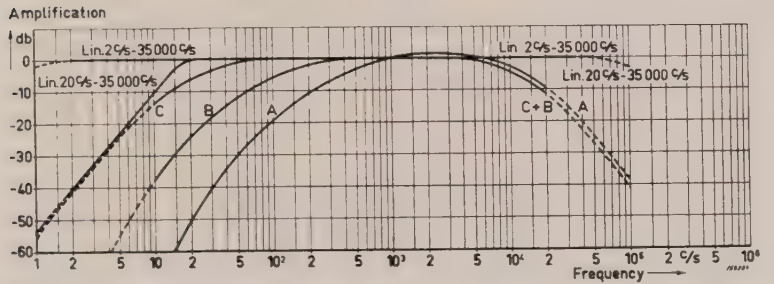


Fig. 13. Typical frequency characteristics of the Spectrometer for sound level measurements. Curves also plotted for "Linear" and "20—35000 c/s" characteristics.

Selection of the Filters.

The switching of the filters from one filter to the next is accomplished by the "Filter Switch", see Figs. 1 and 2, and the center frequency is indicated on a large illuminated scale. The ⅓ octave filters and weighting networks are marked on the outer part, and the 1/1 octave filters on the inner part of the scale. The scale is calibrated from 10 c/s to 31.5 kc/s, although the Spectrometer does not contain filters with center frequencies lower than 40 c/s. The additional calibration of the scale is based on the use of the Extension Filter Set Type 1619 (ZS 0145), which is available as a separate unit and consists of four filters with a bandwidth of ⅓ octave and center frequencies of 16—20—25 and 31.5 c/s. In addition, a 1/1 octave condition with a center frequency of 25 c/s is obtained.

Remote Control. The "Filter Switch" can be manually or automatically operated, the latter being achieved by a remotely controlled electro-magnetic drive unit. Two means of remote control can be obtained, one employing

an external switch in connection with the internal power supply, the other employing an external switch and DC supply (24 Volts, 180 mA). The latter is recommended, as it gives the most noiseless form of switching. The connections to be made to the jack "Remote Control" can be seen in Fig. 14. When the switching action is controlled from the Level Recorder Type 2305 a special Cable AQ 0002 has to be applied between the two instruments.

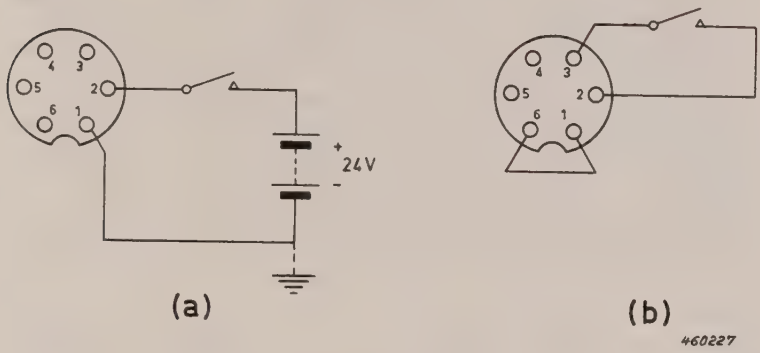


Fig. 14. "Remote Control" (outside view).
(a) External battery.
(b) Single-poled contact only.

Extension Filters. The rotary switch has 50 positions. One complete revolution of the switch thus means 50 successive switchings. Only 34 positions of the 50 are employed for connections to the built-in filters, 16 positions thus being unused. These 16 points are connected to a terminal board at the back of the instrument chassis, (vide Fig. 33 on page 54), and can, when desired, be used for connection of additional external filters. Further, 6 of these points are led to the seven-poled socket marked "Filter Input — Extension Filter", to which the above mentioned Extension Filter Set Type 1619 can be connected. When Type 1619 is not used, or when it is built into the cabinet of the instrument itself, a special adapter is inserted in the "Filter Input — Extension Filter" jack, transforming the seven-poled jack into a 14 mm screened coaxial socket, which then makes connection to the output of the input amplifier. Note should be made that the built-in method only applies to Type 3312 and 3323.

Output Amplifier.

Input Circuit. The output amplifier consists of three stages and shows an input impedance of 1.46 MΩ.

In the input circuit a voltage divider is inserted, containing 4 steps of 10 db and operated by the knob marked "Range Multiplier". With the "Range

Multiplier" switch in position "x 1, 0 db" the amplification of the output amplifier is 10 times. Maximum amplification is obtained with the "Range Multplier" switch in position "x 0.01, —40 db" and is then 1000 times (60 db).

Sensitivity Adjustment. The output amplifier is provided with negative feedback, the amount of which may be varied by two potentiometers. The sensitivity of the apparatus can then be adjusted and thereby calibrated, the reference voltage being used as calibration voltage. One of the potentiometers is in circuit when the "Input Switch" is in position "Condenser Microphone", the other when the switch is in either of the two positions "Direct" or "Input Potentiometer". Separate sensitivity adjustment is therefore obtainable for sound and voltage measurements, this being an additional convenience during practical use of the Spectrometer. The potentiometers can be adjusted with the aid of a screwdriver through holes in the front panel, which are marked "Sensitivity — Condenser Microphone" and "Sensitivity — Amplifier Input".

Output. The output circuit of the amplifier is connected both to the output terminals marked "Recorder" and to the rectifier and meter circuit. The "Recorder" terminals are provided for connection to headphones, oscillograph, level recorder etc. Additionally it can be connected to the compressor input of the Beat Frequency Oscillator Type 1014. The available output impedance from this terminals is 50 Ω.
The amplifiers in the spectrometer are constructed in such a way that they do not clip the signal, if its peak value, after amplification in the output stage, does not exceed a value of 13 db higher that is indicated for full deflection on the meter, i.e. 10 Volts + 13 db $\cong$ 45 Volts peak.

Output Voltage. When the instrument meter gives full deflection, a voltage of 8—10 Volts is available across the "Recorder" terminals.

Rectifier and Meter Circuit.

A switch in the rectifier circuit enables either the true r.m.s., the arithmetical average or half the peak-to-peak value of the input signal to be measured.

R.M.S. MEASUREMENTS

The characteristic for an instrument which should measure the r.m.s. value, is a parabola. By means of a specially constructed circuit of resistors and semiconductor diodes this parabola is simulated. The rectifier circuit employed is a full-wave rectifier and the combined circuit is developed to measure the r.m.s. value of signals with crest factors f_c as high as 5.

$$f_c = \frac{S_{peak}}{S_{rms}} = 5$$

However, due to the peak limiting (45 Volts) of the output amplifier in the Spectrometer Type 2111, the highest deflection for r.m.s. value of the meter pointer when measuring signals with crest factors 5, should not exceed:—

$$S_{rms} = \frac{S_{peak}}{f_c} = \frac{45}{5} = 9 \text{ Volts.}$$

For full deflection the crest factor f_c should not exceed:—

$$f_c = \frac{45}{10} = 4.5$$

The high frequency limit of the Spectrometer should be borne in mind, when measuring signals with many significant harmonics.

At low frequencies the meter pointer will start to fluctuate when the "Meter Switch" is in the position "Fast". This position indicates the one of two possible, "Slow" and "Fast", dynamic characteristics of the meter. When the fluctuation due to the low frequency is too large, the mean value read is no longer the correct value. The Meter Switch should therefore be set in position "Slow". The lower limiting frequency in position "Fast", is of approximately 20 c/s. (sine wave).

ARITHMETICAL AVERAGE MEASUREMENTS

The circuit employed is a full-wave rectifier, enabling the average value of the complete signal to be measured. Care should be taken not to overload the amplifiers when measuring the average value of a complex signal which has high peaks. It is therefore necessary to know the highest peaks, positive or negative, which occur in the measured signal. By means of the two factors, crest factor f_c and form factor f_f, below,

$$f_c = \frac{S_{peak}}{S_{rms}} \qquad f_f = \frac{S_{rms}}{S_{average}}$$

the peak value of the signal may be calculated, provided the average value (read on the meter) and the two factors are known.

$$S_{peak} = f_c \times f_f \times S_{average}$$

As the 45 Volts peak should not be exceeded, when the meter pointer gives full deflection for average value, the highest permissible value for

$$f_c \times f_f = \frac{45}{10} = 4.5.$$

If the meter pointer has not full deflection, the product $f_c \times f_f$ could be proportionally higher.

When measuring signals with many significant harmonics, i.e. pulses, the limiting at the high frequency of the amplifier should be borne in mind.

PEAK MEASUREMENTS

The circuit for measuring peak values is a normal full-wave rectifying circuit. The signal from the output amplifier is applied via a condenser

C_1, vide Fig. 15. Due to this condenser, the deflection on the meter corresponds to the half peak-to-peak value of the signal. That should be taken into account when the positive and negative values of a signal, applied from the output stage, are not equal. In this case, the peak value read on the meter is thus not the maximum that occurs.

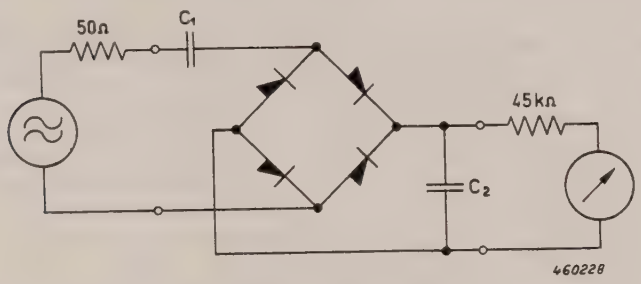


Fig. 15. Electrical circuit of peak rectifier arrangement.

As indicated in Fig. 15 the output resistance of the output stage is approximately 50 Ω, which is the charge resistance for C_1 and C_2. The discharge resistance for C_2 is approximately 45 kΩ. Due to these finite quantities, signals with very thin peaks and high crest factors will be somewhat clipped. The ideal case would be to use a charging resistance of zero and a discharging resistance of infinite which is, of course, impossible to reach in practice. However, even when measuring positive or negative pulses with crest factor 5, refer passage "R.M.S. Measurements", the clipping of the signal will be negligible. Fig. 16 gives an impression of a signal with a crest factor of 5.
The limiting at the high frequency end of the Spectrometer should be taken into consideration when measuring signals with many significant harmonics.

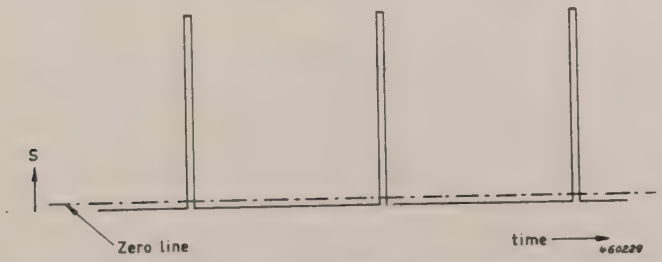


Fig. 16. Example of unsymmetrical signal with a crest factor of approximately 5.

At low frequencies, 20 c/s (sine waves), the "Meter Switch" should be set in position "Slow". The reason is as under "R.M.S. Measurements".
A discription of the working principle of the complete rectifier circuit is given in the B & K Technical Review No. 3-1958.

DAMPING AND GRADUATION OF METER

The two different damping characteristics of the meter "Fast" and "Slow" are in accordance with the standards for sound level meters.
The meter itself is graduated 0—10 and 0—31.5 as well as 0 to 20 db. Furthermore, scales, permitting the direct reading of acoustic absorption coefficients, are provided. These scales should be used when measurements are taken with the Standing Wave Apparatus Type 4002. When utilizing the first three graduations electrical measurements can be read either in mV, volt or in db, re. 1 volt, and acoustical measurements in Sound Pressure Level (S.P.L.) or Sound Level (S.L.) re. 2×10^{-4} μbar. When measuring S.P.L. or S.L. one of the B & K Microphones should be used in conjunction with the Spectrometer. For use of the scales concerning the Standing Wave Apparatus, reference should be made to the instruction book for this apparatus.

Overall Performance of the Instrument.

Signal-to-noise ratio. When the "Range Multiplier" switch is in position "$\times$ 1, 0 db", the signal-to-noise ratio for full scale deflection on the meter is better than 55 db for any setting of the "Meter Range" switch, see also Fig. 17. By using any of the other four positions of the "Range Multiplier" switch, the signal-to-noise ratio for full meter deflection decreases by the same number of db, corresponding to the increase in amplification. To obtain the best ratio between signal and noise voltage, the "Range Multiplier" switch should thus, during measurements, be set to give as low amplification of the output amplifier as possible, preferably "$\times$ 1, 0 db".

Overloading. When measurements are carried out where filters are inserted between the two amplifier sections, care must be taken not to overload the input amplifier. The "Function Selector" should, therefore, first be set to position "Linear", and the amplification of the amplifiers be adjusted as described above. This is necessary, to make sure that no large voltage components exist outside the band-pass of the filters, as, when the filters are inserted, such voltage peaks will not be detectable on the meter and might therefore easily overload the input amplifier. If weak components of a frequency spectrum have to be measured, the amplification should, for the reason given above, be increased by means of the "Range Multiplier" switch until a suitable deflection is obtained on the meter.

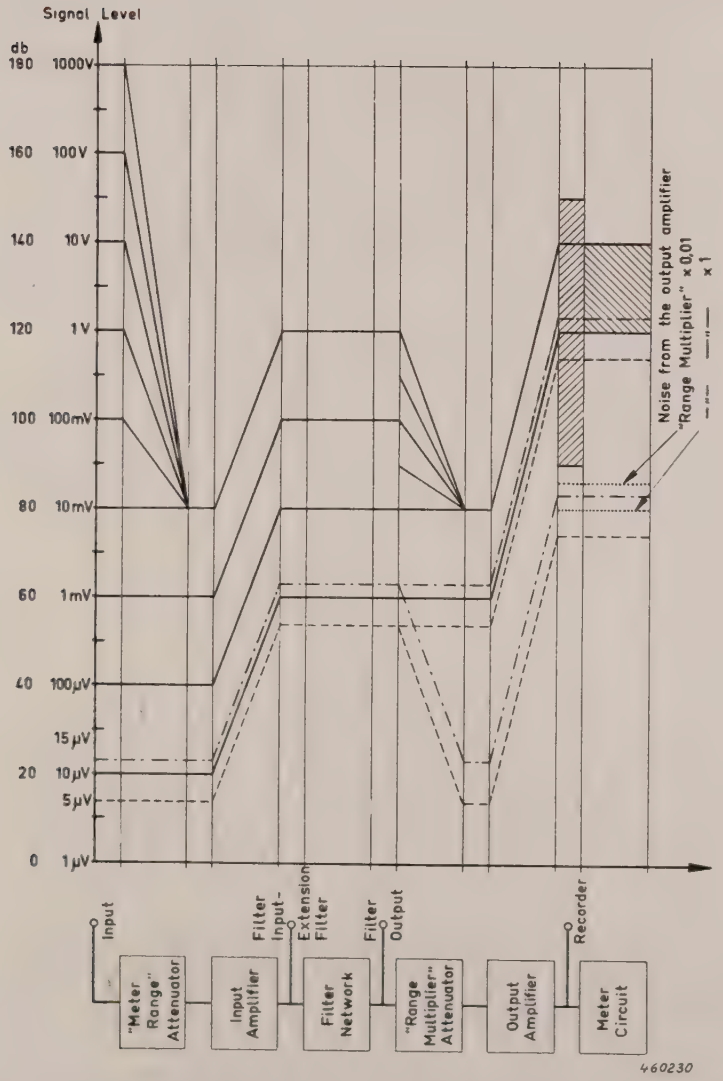


Fig. 17. Sketch showing signal levels at different points in the Spectrometer. Dotted lines indicate noise levels when used as "Linear" amplifier.

Frequency and Phase Response. For the Spectrometer with the "Function Selector" switch in position "Linear, 2—35000 c/s" or "Lin.", typical frequency and phase response curves are shown in Fig. 18.
The two curves shown in the high frequency range indicate the lowest and highest typical phase distortion, obtained for a single apparatus, for all combinations of the "Meter Range" and "Range Multiplier" switches.

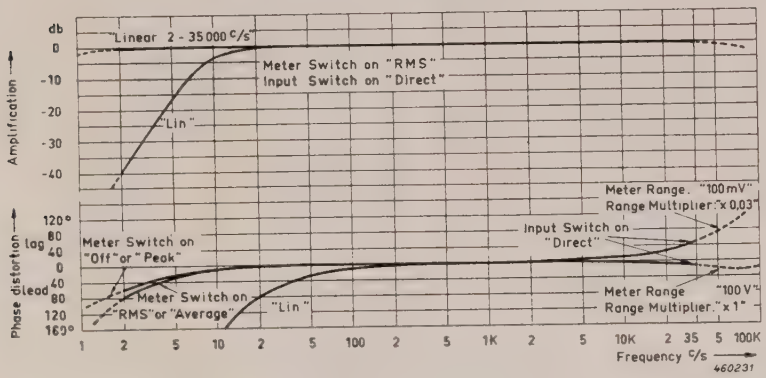


Fig. 18. Overall performance of the instrument, showing frequency and phase response characteristics.

Power Supply.

The power supply section contains three rectifiers, one of which supplies the heater current to the apparatus. Another supplies heater current to the tubes of the B & K Cathode Followers or Preamplifiers, via the "Condenser Microphone" input jack, and a third supplies the necessary anode voltages for the amplifiers, as well as the polarization voltage for the microphone cartridge of the Condenser Microphones. The anode voltage is stabilized with the aid of two neon tubes.

Polarization Voltage. A bushing marked "Polarization Voltage" on the front panel of the apparatus, makes it possible to quickly measure the polarization voltage for the microphone cartridges. Because of the relatively high source resistance, a voltmeter with a resistance not less than 20000 Ω/Volt should be used for this measurement. The voltage can be adjusted by a screwdriver operated potentiometer on the back of the instrument, refer Fig. 19. The adjustment range is 150 to 250 Volts. In case the Spectrometer is used with a Condenser Microphone of the Type 4111, the polarization voltage should be 150 Volts. When used with one of the Condenser Microphones 4131, 4132,

4133 or 4134 the polarization voltage should be 200 Volts. Before the instrument leaves the factory, the voltage is lined to 200 Volts.

Fuse and Selection of correct Power Voltage. The primary side of the power transformer is fused, the fuse being placed on the rear of the apparatus, see also Fig. 19.

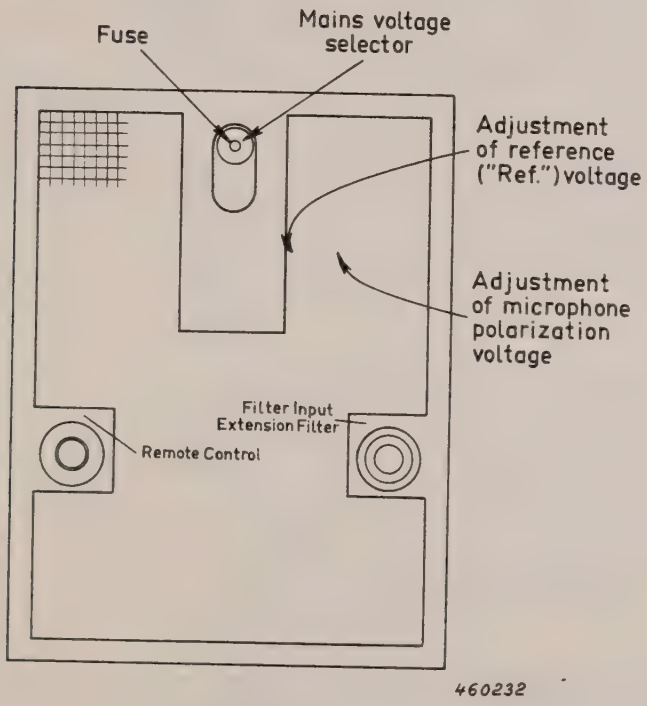


Fig. 19. Rear view of Spectrometer.

The equipment should be operated from a 50 to 400 c/s power line and can be set for mains voltages of 115 — 127 — 150 — 220 or 240 Volts. The power consumption is approximately 50 Watts. Adjustment for the different supply voltages can be carried out on the rear of the apparatus, refer Fig. 19. After the fuse is removed, the inner part of the combined voltage selector and fuse holder is turned by a coin or similar means until the white mark points on the desired value.

If the equipment is to be operated from an accumulator, or from other DC supplies, the use of a vibrator or a rotary converter is necessary.

Identification of Control Knobs, Terminals etc.

Front Plate.

Refer Fig. 1 on page 5.

"Polarization Voltage":	For measuring of the microphone polarization voltage. A DC voltmeter with an internal resistance of at least 20ooo ohm/Volt should be used.
"Condenser Microphone":	Input terminal for the B & K Condenser Microphones (Cathode Followers) and Preamplifiers.
"Input Potentiometer":	For continuous variation of input signal attenuation.
"Sensitivity, Condenser Microphone":	Screwdriver operated potentiometer, for adjustment of sensitivity, when input "Condenser Microphone" is used.
"Input Switch":	Selection of one of the three input facilities "Input Potentiometer", should be used only for relative measurements at the same frecuency. "Direct". The signal is applied direct from the "Amplifier Input" to the attenuator "Meter Range". "Condenser Microphone".
»Amplifier Input":	The signal is applied to the attenuator "Meter Range" either direct or via the "Input Potentiometer".
"Ground":	Connected to the frame of the apparatus.
"Automatic Switching":	"On". The connection of the electromechanical drive unit for filter switching, is established with "Remote Control". "Off". Connection is broken.
"Meter Range":	Step attenuator, 20 db, for attenuation of input signal.
"Power":	For switching off and on the power for the apparatus.

"Meter Switch": For selection of the three different meter indicating properties

"Average"
"Peak" (half peak to peak)
"R.M.S."

The three positions to the left gives the smallest damping of the indicating meter deflection. The positions to the right gives the highest damping.
In the middle position "Off", the meter circuit is disconnected.

"Recorder": Output terminal.

"Sensitivity, Amplifier Input": Screwdriver operated potentiometer for adjustment of sensitivity when terminal "Amplifier Input" is used.

"Range Multiplier": Step attenuator, 10 db, for attenuation of the signal level between the filter outputs and output amplifier.

"Filter Output": Connection to the input of the output amplifier via the attenuator "Range Multiplier".

»Ground": Connection to frame of apparatus.

"Function Selector": Selection of the various functions.

"External Filter". An external filter set, connected to the terminals "Filter Input-Extension Filters" (on the rear of the apparatus) and "Filter Output", is inserted between the two amplifier sections.

"Linear, 2—35000 c/s". The equipment is set up as a linear vacuum tube voltmeter.

"⅓ Octave, 0 db". The ⅓ Octave Filters and the Weighting Networks, also possible ⅓ octave external filters, can be selected by the "Filter Switch".

"Octave, —10 db". The Octave Filters and the Weighting Networks, also possible octave external filters, can be selected by the "Filter Switch". An extra attenuation of 10 db is inserted.

"Filter Switch": For selection of the different filters, weighting networks, and possible connected extension filters.

Rear of Equipment.

Refer Fig. 19 on page 24.

"Remote Control": Connections for remote controlling of the Filter Switch.

Fuse and Mains Voltage Selector: The fuse should be of 1 amp.

"Filter Input — Extension Filter": The terminal is devided into two parts: Filter Input and Extension Filter.

"Filter Input". When the special adapter (transforming the 7-poled jack into the 14 mm coaxial jack) is inserted, connection to the output of the preamplifier is achieved, when "Function Selector" is in position "External Filter".

NOTE: A DC voltage of approximately 75 Volts is present.

"Extension Filter". The 7-poled jack is connected to the "Filter Switch" enabling extension filters to be switched in one by one.

NOTE: When extension filters are not connected, the special adaptor should always be inserted in the jack, as this "grounds" all the positions on the "Filter Switch" intended for extension filters.

Adjustment Potentiometers for:— The reference voltage, intended for calibration of the apparatus.

The microphone polarization voltage.

Operation

General 29

Voltage Measurements 29

Analysis of Audio Frequency Voltages with 1/3 Octave or Full Octave Filters 30

Automatic Recording of Voltage Analysis 31

A. Recording of Single Spectrograms 32
B. Employment of Different Potentiometers 36
C. Reading of Absolute Values from the Spectrogram 36

Automatic Recording of Sound Spectrograms 37

A. Recording of Single Spectrograms 38
B. Evaluation of Sound Spectrograms 41
C. Reading of Absolute Values from the Spectrogram 41

Spectrometer set up for Sound Surveys or as Precision Sound Level Meter 45

Calibration or checking of Measuring Arrangements for Sound Investigation by Means of Calibrated Sound Source 47

I Pistonphone 48
II Noise Source 49

Operation

GENERAL

Firstly ensure that the instrument is adjusted to the appropriate power supply voltage*) and then switch on with the aid of the switch marked "Power" on the front panel. Immediately the meter and filter switch scales should light up, and after allowing a warming-up of a few minutes the apparatus is ready for use.

Voltage Measurements.

The apparatus can be used as a linear tube voltmeter, in the audio frequency range, for absolute and relative measurements of true RMS and average values. When peak values are measured the reader is referred to the Description page 19. Before actually carrying out the measurements, the sensitivity of the instrument should be checked by means of the built-in reference voltage.

I. Calibration.

1. The control knobs should be set as follows:—

"Input Switch":	"Direct"
"Meter Range":	"Ref."
"Meter Switch":	"Fast", "RMS"
"Range Multiplier":	"× 1, 0 db"
"Function Selector":	"Linear, 2—35000 c/s"

Control knobs not mentioned may be in any position.

2. The meter should now show a deflection to the red mark on the scale. Possible deviations being corrected by means of the potentiometer marked "Sensitivity — Amplifier Input" on the front panel, with the aid of a screwdriver.

II. Measuring.

1. The voltage to be measured is fed to the "Amplifier Input" socket, and the input switch is kept in position "Direct" if absolute measurements are desired, or set to position "Input Potentiometer" if relative measurements are to be made (see Description, page 6).
2. The "Meter Switch" is set according to the desired type of rectification, i.e. "Average", "Peak" or "RMS". If frequencies below 20 c/s are to be measured, one of the positions "Slow" should be used.

*) Refer Description page 24.

3. The "Function Selector" is kept in position "Linear", and the desired voltage range chosen by means of the "Meter Range" and "Range Multiplier" switches. If possible, the "Range Multiplier" switch should be kept in position "× 1 (0 db)", the reason for this being given under "Description", page 21.

III. Reading on Indicating Meter.

Volts. The input signal voltage, which gives full deflection on the meter, is found by multiplying the number of mV or V indicated on the chosen position of the "Meter Range" switch by the factor indicated on the position of the "Range Multiplier" switch. If, for example:—

"Meter Range" switch is in position "1 V, —20 db"

"Range Multiplier" switch is in position "× 1, 0 db"

Full deflection on the meter occurs for 1 Volt × 1 = 1 Volt.

By using the full amplification of the apparatus, full deflection on the meter corresponds to an input signal voltage of 10 mV × 0.01 = 100 μV.

Db re. 1 Volt. The voltage level in db, relative to 1 V, indicated on the meter will be found by adding the db-values indicated by the position of the "Meter Range" and "Range Multiplier" switches to the number of db indicated on the instrument meter. An example will illustrate this:—

"Meter Range" in position "—60 db"

"Range Multiplier" in position "—10 db"

Deflection on the meter: + 20 db.

— 60 db — 10 db + 20 db = —50 db re. 1 V = 3.16 mV

IV. Recording.

The voltage measured may be recorded on a Level Recorder, for example Type 2305, this being connected to the output socket marked "Recorder".

Analysis of Audio Frequency Voltages with 1/3 Octave or Full Octave Filters.

When complex voltages are analysed, care should be taken not to overload the amplifiers (see also "Output Amplifier", page 18).

I. Calibration.

The instrument is calibrated and a suitable deflection on the meter is obtained as described under "Voltage Measurements".

II. Measuring.

Analysing can then be carried out by setting the "Filter Switch" to the desired filter and the "Function Selector" to either "⅓ Octave 0 db" or "Octave — 10 db". In the latter position 10 db should be added to the meter deflection (see the Description, page 13).

When weak components of a frequency spectrum are to be measured, the

amplification of the instrument should be increased only by means of the "Range Multiplier" switch.

III. Reading on Indicating Meter.
Vide under "Voltage Measurements", item III.

Remote Control.
Two means of remote controlling the Filter Switch are offered, one having an external switch only and utilising the internal power supply, the other using an external supply (24 V DC) with a control switch in series outwith the equipment.
The connections to be made can be seen in Fig. 14 on page 17.

Automatic Recording of Voltage Analysis.

If the Spectrometer is connected to one of the B & K Level Recorders, e.g. Type 2305, the analysis of complex signals can be recorded automatically and will then be available in the form of a spectrogram. By using preprinted, frequency calibrated recording paper on the Level Recorder, the spectrogram will appear as a calibrated frequency amplitude diagram of the measured signal. For this operation the paper drive of the Level Recorder must be synchronized with the filter switching moment of the Spectrometer.

MEASURING ARRANGEMENT
Connect the instruments as shown in Fig. 20.
The "Remote Control" socket on the back of the Spectrometer should be connected to the six-poled "Remote Control" socket on the Level Recorder, by the cable AQ 0002.
Then proceed as follows:—

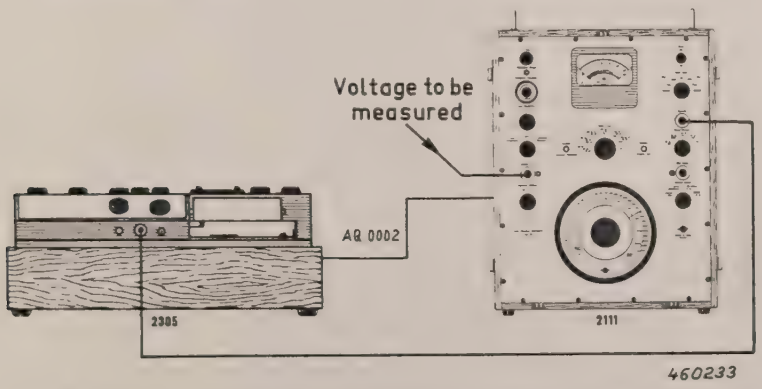


Fig. 20. Measuring arrangement for automatic recording of voltage analyses.

A. RECORDING OF SINGLE SPECTROGRAMS

I. Calibrate the Spectrometer as outlined under "Voltage Measurements", item I, page 29.

II. Calibration of the Level Recorder.

1. Potentiometer 50 db employed. For potentiometers with other ranges refer para B, page 36.
2. Set control knobs as follows:—
   "Potentiometer Range db" to "50"
   "Rectifier Response" to "R.M.S."
   "Lower Limiting Frequency" to "20"
   "Writing Speed": 50 mm paper: 500 mm/sec, large figures.*)
   100 mm paper: 1ooo mm/sec, small figures.*)
   "Paper Drive" to »Stop" and "Forward".
   "Single Chart-Cont. Record." in its upper position
   "Power" to "On"
   Allow a few minutes for warming up, then switch
   "Motor" to "On"
   "Input Attenuator" to "10"
3. By means of the "Input Potentiometer" the deflection of the stylus is adjusted to full deflection minus 4 db. (Using 50 db Range Potentiometer, 50—4 = 46 db).

III. Adjustment of the Single Chart automatic stop:—

1. Insert the desired type of frequency calibrated paper. If necessary, see the instruction manual for Level Recorder Type 2305.
2. Pull the Gear Lever (ratio 1 : 10) to its outer position. The Lever is marked X in Fig. 21.
3. Turn the screw S shown in Fig. 21 by the aid of a screwdriver, until the marking cut in the screw is in its upper position.
4. Set the "Paper Speed" to 10 mm/sec, small figures. The spring loaded knob is operated by pulling and turning.
5. The toggle switch "Paper Drive" is set to "Start", whereby the paper starts moving. If not, press the pushbutton "Single Chart-Cont. Record". After one chart length or less the paper automatically stops.
6. Move the recording paper by means of the finger wheel Z shown in Fig. 21 until the writing stylus points at the "10" c/s line.

---

*) By this combination of "Lower Limiting Frequency" and "Writing Speed" setting, the Level Recorder is operating in an unnormal condition and therefore tends to overswing as visible on the recording in Fig. 22. The unnormal condition is used only during synchronization to give an unambiguous indication of the filter switching point.

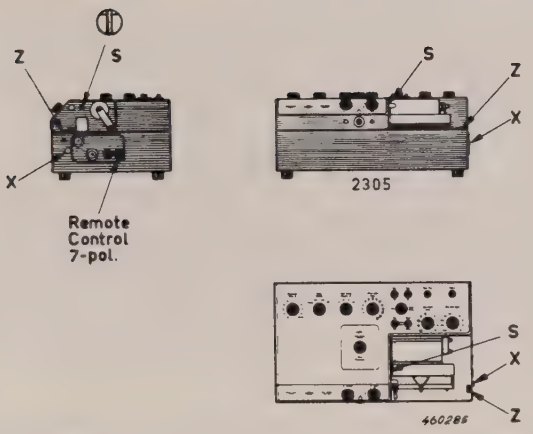
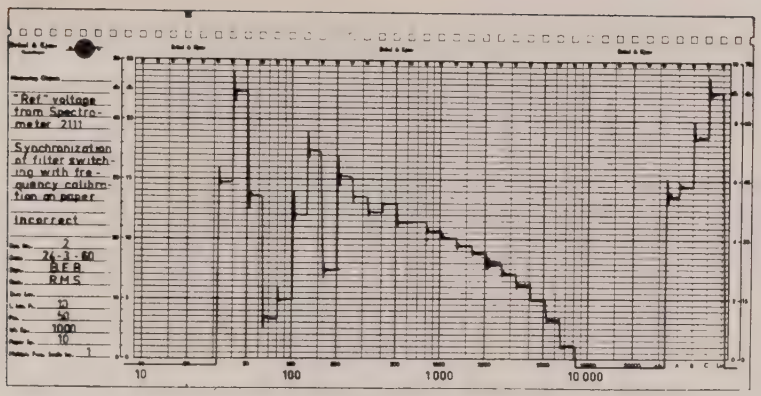


Fig. 21. Level Recorder with indication of: Synchronizing lever "X", screw "S", and finger wheel "Z".

IV. Synchronization between Level Recorder and Spectrometer.

The switching moment of the "Filter Switch" on the Spectrometer can now be synchronized with the paper movement.

1. When proceeding from above the following control knobs on the Spectrometer have to be set to:
   "Function Selector" "⅓ Octave — 0 db"
   "Automatic Switching" "Off"
   "Filter Switch" "10"
   "Automatic Switching" "On"
2. The control knobs on the Level Recorder have to be moved as follows:
   Set "Paper Drive" to "Stop".
   Press the pushbutton marked "Single Chart-Cont. Record".
   The paper starts moving, and then the reference voltage commences to be recorded.
   The pushbutton should be released when the paper has moved to about the "200" — "300" c/s line.
3. Correct synchronization is obtained when the switching over from the "80" c/s to the "100" c/s filter takes place on the line "90" c/s, refer Fig. 22a and b.
   To ensure that synchronization is achieved within the proper ⅓ octave filter the component of the power supply fundamental frequency should be represented as the highest value on the spectrogram within the filter covering this fundamental. From Fig. 22b it is seen that the fundamental therein 50 c/s is the highest value and rests



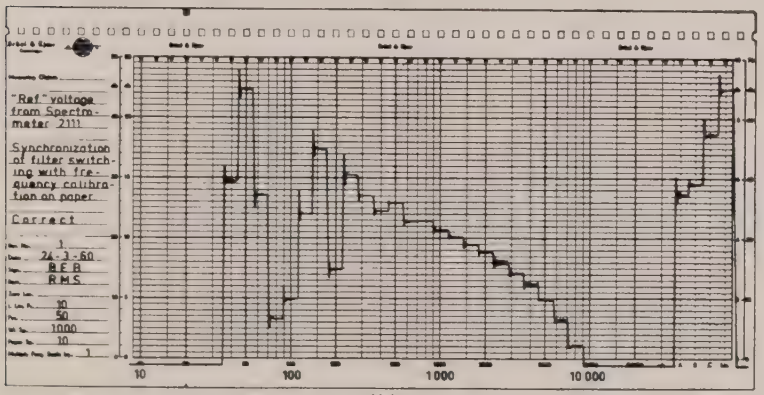


Fig. 22. Synchronization between writing paper and filter switching.
(a) Incorrect.
(b) Correct.
(Concerning the overswing on the recording vide the footnote on page 32).

within the filter concerned. In the case of a 60 c/s power supply frequency the highest value would be contained within the 63 c/s filter.

4. If the synchronization is incorrect, the paper should be shifted by the finger wheel Z.

   NOTE: To avoid the effect of play between the gear wheels, the paper should always be shifted in a manner, so that it

approaches the correct point in the reverse direction. If, for example, it has to be shifted corresponding to a higher frequency, i.e. forward direction, the paper is shifted a little beyond, and finally reversed to the desired point.

To be able to see how far the paper has to be shifted, it is recommended to draw a line by means of the stylus, when the paper has stopped. By using this line, the paper is now shifted the required distance to give correct synchronization, this being easily seen from the previous recording. To draw the line, the stylus is given a deflection which may be obtained by pressing the knob "100 mV. Ref.". Should the paper have to be shifted equal to a lower frequency the respective distance may be marked on the paper beforehand.

5. To check the synchronization, run the recording to about the "2000" — "3000" c/s line. When synchronized correctly the switching from the "800" c/s to the "1000" c/s filter should now take place at the "900" c/s line. If this is not the case, run the paper to the following charted portion and repeat from item IV. 2.
6. "Paper Drive" is set to "Start", whereby the paper moves to the pre-selected stop.

V. Adjustment to the Signal.

1. The control knobs "Rectifier Response", "Lower Limiting Frequency", "Writing Speed" and "Paper Speed" on the Level Recorder are set to positions, whichever are desired for the measurement in question.
2. The voltage to be measured is applied to the "Amplifier Input" on the Spectrometer. Keeping control knobs in position as outlined above, change the following on the Spectrometer to:—

"Function Selector":	"Linear, 2—35000 c/s"
"Meter Range" and "Range Multiplier":	are set so that a suitable deflection of the writing stylus is obtained (40—45 db for 50 db Range Potentiometer employed). The "Range Multiplier" should be in position as near "× 1, 0 db" as possible. The reason being given in the Description on page 21.
"Meter Switch":	"Off" (recommended at low frequencies or/and high amplitudes).

VI. Recording.

On proceeding from "Adjustment to the Signal" the recording can be started when:

1. The "Function Selector" is set to "⅓ Octave, 0 db" or "Octave, —10 db", whichever is desired for the measurement.
2. The pushbutton "Single Chart-Cont. Record." being operated, allowing the recording to start.

3. It is recommended, additionally, to write down on the recording paper the positions of the "Meter Range", "Range Multiplier" and "Function Selector" controls.

B. EMPLOYMENT OF DIFFERENT POTENTIOMETERS

When using other than a 50 db Potentiometer during measurement, the following should be taken into account:—

I. Item A II through A IV is firstly carried out with a 50 db Range Potentiometer.

II. Item A II is repeated with the desired Range Potentiometer inserted but with the modifications in item A II 2 as follows:—

1. "Function Selector" on Spectrometer to "Linear, 2—35000 c/s".
2. "Potentiometer Range" set to the Potentiometer employed.
3. "Writing Speed" set as follows:—

Range Potentiometer	50 mm paper	100 mm paper
10	"250 mm/sec"	"500 mm/sec"
25	"250 mm/sec"	"500 mm/sec"
75	"250 mm/sec"	"500 mm/sec"

4. Paper Drive to "Start" and "Forward".
5. "Input Attenuator" is set to:—
   10 db Range Potentiometer: "30"
   25 db Range Potentiometer: "30"
   75 db Range Potentiometer: "0"
6. By means of the "Input Potentiometer" the deflection of the stylus is adjusted to:—

Range Potentiometer	Deflection of Stylus
10	10— 4 = 6 db
25	25— 4 = 21 db
75	75—19 = 56 db

Then continue with item A V through A VI.

C. READING OF ABSOLUTE VALUES FROM THE SPECTROGRAM

1. Range Potentiometer 10, 25 and 50 db employed.
   The absolute value read on the spectrogram and referred to the "Amplifier Input" of the Spectrometer is:—
   The value in db on the spectrogram + the sum of numbers of db indicated by "Meter Range", "Range Multiplier" and "Function Selector" — 50 db, re 10 V.
   The "50 db" mentioned is due to the use of a 50 db Potentiometer.

Example:
50 db Potentiometer
Deflection of the stylus: 46 db
"Meter Range": "+ 20 db"
"Range Multiplier": "—10 db"
"Function Selector": "1/3 Octave, 0 db"
46 db + 20 db — 10 db + 0 db — 50 db = + 6 db, re 10 V = 20 V

Example:

25 db Potentiometer
Deflection of the stylus: 13 db
"Meter Range": "—40 db"
"Range Multiplier": "0 db"
"Function Selector": "Octave, —10 db"
13 db — 40 db + 0 db — 10 db — 25 db = — 62 db, re 10 V = 8 mV.

2. Range Potentiometer 75 db employed.
   The absolute value read is:—
   The value in db on the spectrogram + the sum of numbers of db indicated by "Meter Range", "Range Multiplier" and "Function Selector" — 60 db, re 10 V.

   NOTE: Due to the risk of overloading the output amplifier in the Spectrometer, the voltage from this should not exceed 45 V peak. When for instance recording a sine wave in position R.M.S. the deflection of the stylus should not exceed 70 db.

Example:

75 db Potentiometer
Deflection of the stylus: 60 db
"Meter Range": "0 db"
"Range Multiplier": "— 10 db"
"Function Selector": "1/3 octave, 0 db"
60 db + 0 db — 10 db + 0 db — 60 db = — 10 db, re 10 V = 3.16 V

3. If it is required to record voltages in db above a certain reference value, the voltage equal to 0 db deflection of the stylus is found by means of the table given below.

Voltage on "Amplifier Input" re 0 db line on recording paper	10 μV	100 μV	1 mV	10 mV	100 mV	1 V	10 V	100 V	Range Potentio-meter used
The sum of db indicated by "Meter Range", "Range Multiplier" and "Function Selector"	db	db	db	db	db	db	db	db	
		—90	—70	—50	—30	—10	+10	+30	10 db
	—70	—50	—30	—10	+10	+30			50 db

Automatic Recording of Sound Spectrograms.

One of the most important features of the combination Spectrometer, B & K Condenser Microphone and Level Recorder is its ability, to record sound spectrograms automatically.
Some typical examples of this type of measurements are given under "Application". The calibration, synchronization and measuring procedures are as follows:

MEASURING ARRANGEMENT

Connect the Spectrometer and Level Recorder as shown in Fig. 23.

The "Remote Control" socket on the rear side of the Spectrometer should be connected to the six-poled "Remote Control" socket of the Level Recorder by means of the cable AQ 0002.

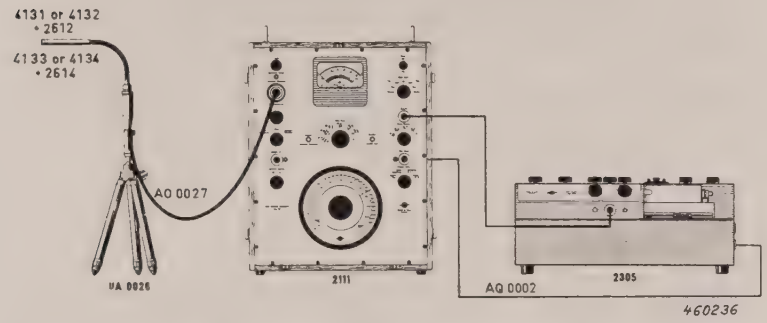


Fig. 23. Measuring arrangement for automatic recording of sound spectrograms.

A. RECORDING OF SINGLE SPECTROGRAMS

I. Set-up and Calibration.

The procedure outlined in "Automatic Recording of Voltage Analysis", paragraph A, "Recording of Single Spectrograms", should be followed from item I to IV (incl.).

NOTE: In most cases whenever sound measurements are carried out, a 50 db Range Potentiometer will be suitable. However, in some cases it might be advantageous to utilize potentiometers with another range. The procedure laid down in the above mentioned chapter under paragraph B on page 36 can, in such a case, be followed.

II. Calibration according to the selected Microphone.

The measuring arrangement has now to be calibrated due to the Microphone employed. This can be done by:—

Microphone 4131 or 4132 employed.

Employment of the reference voltage in the Spectrometer and the correction factor "K" valid for the

Microphone 4133 or 4134 employed.

1. Check the microphone polarization voltage. Further instructions concerning this is given in the

Microphone 4131 or 4132 employed.

respective Microphone. If desired, information of "K" is given in Fig. 24.

1. Check the microphone polarization voltage. Further instructions concerning this is given in the Description of the Power Supply, page 24.
2. Apply the Condenser Microphone and its matching Cathode Follower as shown in Fig. 23. Allow a few minutes to warm up.

Microphone 4133 or 4134 employed.

Description of the Power Supply, page 24.

2. Apply the Condenser Microphone and its matching Cathode Follower as shown in Fig. 23. Allow a few minutes to warm up.
3. The control knobs of the Spectrometer should be operated as follows:—

   "Input Switch" to "Condenser Microphone"

   "Function Selector" to "Linear, 2—35000 c/s"

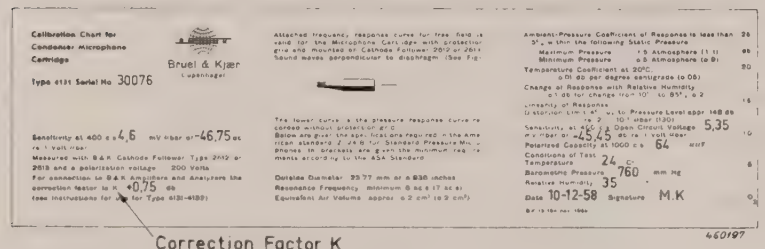

Calibration Chart for
Condenser Microphone
Cartridge
Bruel & Kjær
Copenhagen
Type 4131 Serial No 30076
Sensitivity at 400 c/s 4,6 mV/bar or -46,75 db re 1 volt/bar
Measured with B&K Cathode Follower Type 2612 or 2613 and a polarization voltage 200 Volts
For connection to B&K Amplifiers and Analyzers the correction factor is K +0,75 db
(see instructions for use for Type 4131-4189)
Correction Factor K
460197

Fig. 24. Typical microphone calibration chart with indication of the correction factor "K".

3. The control knobs of the Spectrometer should be operated as follows:—

   "Input Switch" to "Condenser Microphone"

   "Function Selector" to "Linear, 2—35000 c/s"

   The other control knobs are kept as described above.
4. The deflection on the indicating meter should now be adjusted to the red mark plus the correction factor "K" of the Microphone. This being done by means of the potentiometer "Sensitivity, Condenser Microphone". The other control knobs being kept as described above.
4. Adjust the deflection of the indication meter pointer to the red mark on the scale by turning the screwdriver operated potentiometer "Sensitivity, Condenser Microphone".
5. Increase the sensitivity of the Level Recorder by means of the "Input Potentiometer", and, if necessary, by the "Input Attenuator" to:—

   the correction factor "K" db — 10 db.

Microphone 4131 or 4132 employed.

"Sensitivity, Condenser Microphone" accessible on the front.

Example 1.

"K" = 1.5 db.
The pointer has to be adjusted to 16 db + 1.5 db = 17.5 db
16 db corresponds to the red mark.

Example 2.

"K" = — 0.3 db
The pointer has to be adjusted to 16 db — 0.3 db = 15.7 db

Microphone 4133 or 4134 employed.

where "K" is the correction factor of the Microphone. If desired, information concerning this factor is given in Fig. 24.

Example 1.

"K" = 13.3 db
The sensitivity of the Level Recorder should be increased by:—
13.3 db — 10 db = 3.3 db

Example 2.

(50 db Range Potentiometer).
"K" = 16 db
The sensitivity of the Level Recorder should be increased by:—
16 db — 10 db = 6 db
The stylus should then in reality rest at 46 db + 6 db = 52 db.
This is of course not possible as the full deflection is equal to 50 db.
A way of increasing the sensitivity might be:—

(a) Decrease sensitivity by "Input Potentiometer"
10 db — 6 db = 4 db
(b) Increase sensitivity 10 db by "Input Attenuator"
The total increase is then
— 4 db + 10 db = 6 db.

The measuring arrangement has now been calibrated so, that an absolute reading of the S.P.L. value, present on the microphone diaphragm, can be carried out on the spectrogram. Further information is given in a following paragraph "Reading of Absolute Value of the Spectrogram". For absolute reading of the indicating meter deflection, reference is made to "Spectrometer set up for Sound Surveys or as Precision Sound Level Meter", page 47.

III. Adjustment to the Signal.

Sound to be analysed is exposed to the Microphone.

1. The control knobs "Rectifier Response", "Lower Limiting Frequency", "Writing Speed" and "Paper Speed" on the Level Recorder are set to positions, whichever are desired for the measurements in question.
2. Keeping other control knobs in positions as outlined above, the following knobs on the Spectrometer have to be set to:—

"Meter Range" and "Range Multiplier":	are set so that a suitable deflection of the writing stylus is obtained. (40—45 db for 50 db Range Potentiometer employed). The "Range Multiplier" should be in a position as near "× 1, 0 db" as possible, the reason being given in the Description on page 21.
"Meter Switch":	"Off" (recommended at low frequencies or/and high amplitudes).

IV. Recording.

On proceeding from "Adjustment to the Signal" the recording can be started when:—

1. The "Function Selector" is set to "⅓ Octave, 0 db" or "Octave, —10 db", whichever is desired for the measurement.
2. The pushbutton "Single Chart — Cont. Record." is operated, allowing the recording to start.
3. Additionally, it is recommended to write down on the recording paper the positions of "Meter Range", "Range Multiplier" and "Function Selector" controls.

B. EVALUATION OF SOUND SPECTROGRAMS

Sound Pressure Level (S.P.L.) value is indicated when the "Filter Switch" on the Spectrometer is in position "Lin.", see Fig. 25a and b.

When the Spectrometer is switched to analyse with ⅓ Octave Filters, the Sound Pressure Level within ⅓ octave is measured only, and is indicated when the Spectrometer "Filter Switch" is in any of the positions from "40" to "31500". See Fig. 25a. When the Spectrometer is used with Extension Filter Set Type 1619, or ZS 0145, the ⅓ Octave S.P.L. value is obtained, when the filter switch is in any position between "16" and "31500".

When switching the Spectrometer to Octave Filters, the Sound Pressure Level with a bandwidth of 1 octave is measured only.

Sound Level is measured when the Filter Switch on the Spectrometer is in one of the positions "A", "B" or "C" and the Function Selector in "⅓ Octave, 0 db" or "Octave, —10 db". See also Fig. 25a and b.

When the measuring arrangement is calibrated as described in the previous paragraphs the above mentioned levels can all be found from the recorded spectrogram, vide the following paragraph.

C. READING OF ABSOLUTE VALUES FROM THE SPECTROGRAM

When the calibration procedure is carried out as described above in item A. I and II the absolute value in S.P.L. or S.L. on the diaphragm of

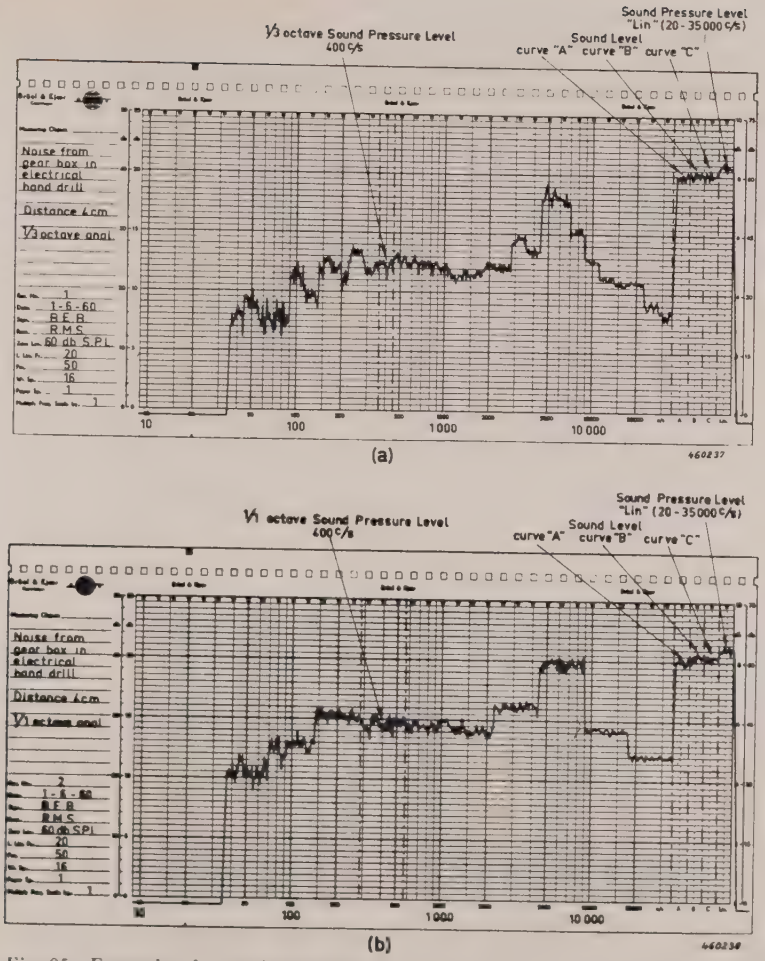


Fig. 25. Example of recorded spectrogram with indication of Sound Pressure Level and Sound Level.
(a) ⅓ Octave analysis.
(b) 1/1 Octave analysis.

the Microphone, read on the spectrogram, will be:—

Microphone 4131 or 4132 employed.

1. 50 db Range Potentiometer applied:

Microphone 4133 or 4134 employed.

1. 50 db Range Potentiometer applied:—

Microphone 4131 or 4132 employed.

The value in db on the spectrogram
+ the number of db S.L. indicated by "Meter Range"
+ the sum of numbers of db indicated by "Range Multiplier" and "Function Selector"
— 30 db

Example 1.
Deflection of the stylus: 46 db
Position of "Meter Range": "60 db S.L."
Position of "Range Multiplier": "0 db × 1"
Position of "Function Selector": "1/3 Octave, 0 db"
46 db + 60 db + 0 db + 0 db — 30 db = 76 db S.P.L. or S.L.

Example 2.
Deflection of the stylus: 10 db
Position of "Meter Range": "80 db S.L."
Position of "Range Multiplier": "— 10 db × 0.3"
Position of "Function Selector": "Octave, — 10 db"
10 db + 80 db — 10 db — 10 db — 30 db = 40 db S.P.L. or S.L.

2. 10 db Range Potentiometer applied:—
The value in db on the spectrogram
+ the number of db S.L. indicated by "Meter Range"
+ the sum of numbers of db indicated by "Range Multiplier" and "Function Selector"
+ 10 db

3. 25 db Range Potentiometer applied:—

Microphone 4133 or 4134 employed.

The value in db on the spectrogram
+ the number of db S.L. indicated by "Meter Range"
+ the sum of numbers of db indicated by "Range Multiplier" and "Function Selector"
— 20 db

Example 1.
Deflection of the stylus: 46 db
Position of "Meter Range": "60 db S.L."
Position of "Range Multiplier": "0 db × 1"
Position of "Function Selector": "1/3 Octave, 0 db"
46 db + 60 db + 0 db + 0 db — 20 db = 86 db S.P.L. or S.L.

Example 2.
Deflection of the stylus: 10 db
Position of "Meter Range": "80 db S.L."
Position of "Range Multiplier": "— 10 db × 0.3"
Position of "Function Selector": "Octave, — 10 db"
10 db + 80 db — 10 db — 10 db — 20 db = 50 db S.P.L. or S.L.

2. 10 db Range Potentiometer applied:—
The value in db on the spectrogram
+ the number of db S.L. indicated by "Meter Range"
+ the sum of numbers of db indicated by "Range Multiplier" and "Function Selector"
+ 20 db

3. 25 db Range Potentiometer applied:—

Microphone 4131 or 4132 employed.

The value in db on the Spectrogram
+ the number of db S.L. indicated by "Meter Range"
+ the sum of numbers of db indicated by "Range Multiplier" and "Function Selector"
— 5 db

4. 75 db Range Potentiometer applied:—
The value in db on the spectrogram
+ the number of db S.L. indicated by "Meter Range"
+ the sum of numbers of db indicated by "Range Multiplier" and "Function Selector"
— 40 db

Microphone 4133 or 4134 employed.

The value in db on the spectrogram
+ the number of db S.L. indicated by "Meter Range"
+ the sum of numbers of db indicated by "Range Multiplier" and "Function Selector"
+ 5 db

4. 75 db Range Potentiometer applied:—
The value in db on the spectrogram
+ the number of db S.L. indicated by "Meter Range"
+ the sum of numbers of db indicated by "Range Multiplier" and "Function Selector"
— 30 db

NOTE: For 75 db Range Potentiometers the calibration is different from that which is valid for the three other Range Potentiometers, refer "Automatic Recording of Voltage Analysis", para B on page 36, which is also used for sound spectrogram recordings.

Due to the risk of overloading, the voltage from the output amplifier in the Spectrometer should not exceed 45 V peak.

The calculation of the formulas used by the different Range Potentiometers, item 1, 2, 3, and 4 above, can be seen from the general formula:—

Microphone 4131 or 4132.

The value in db on the spectrogram
+ the number of db S.L. indicated by "Meter Range"
+ the sum of numbers of db indicated by "Range Multiplier" and "Function Selector"
— db deflection stated for calibration of the Level Recorder*)
— 4 db + 20 db

Microphone 4133 or 4134.

The value in db on the spectrogram
+ the number of db S.L. indicated by "Meter Range"
+ the sum of numbers of db indicated by "Range Multiplier" and "Function Selector"
— db deflection stated for calibration of the Level Recorder*)
— 4 db + 20 db + 10 db

*) Refer "Automatic Recording of Voltage Analysis", para A II item 3 or para B II item 6.

Microphone 4131 or 4132.

Example:

75 db Range Potentiometer.
The value in db on the spectrogram
+ the number of db S.L. indicated by "Meter Range"
+ the sum of numbers of db indicated by "Range Multiplier" and "Function Selector"
— 56 db — 4 db + 20 db
The last line in the formula being — 40 db, refer item 4 above.

Microphone 4133 or 4134.

Example:

50 db Range Potentiometer.
The value in db on the spectrogram
+ the number of db S.L. indicated by "Meter Range"
+ the sum of numbers of db incated by "Range Multiplier" and "Function Selector"
— 46 db — 4 db + 20 db + 10 db
The last line in the formula being — 20 db, refer item 1 above.

Spectrometer set up for Sound Surveys or as Precision Sound Level Meter.

In several cases it is desired to measure the Sound Pressure Level or the Sound Level by means of the Spectrometer, giving a direct reading.

I. Calibration.

The combined Spectrometer and Condenser Microphone may be calibrated in the following way:—

Microphone 4131 or 4132 utilized.

Employment of Spectrometer Reference Voltage and Microphone Correction Factor "K". Information of "K" is given in Fig. 24, page 39.

1. Check the microphone polarization voltage (if necessary, see Description, page 23).
2. Connect the Condenser Microphone and its matching Cathode Follower as shown in Fig. 26.
3. The control knobs should be set as mentioned below:—
   "Input Switch": "Condenser Microphone"
   "Meter Range": "Ref."
   "Meter Switch": "Fast" "RMS"
   "Range Multiplier": "0 db × 1"
   "Function Selector": "Linear, 2—35000 c/s"
   Control knobs not mentioned can be in any position.
4. Allow a few minutes to warm up.

Microphone 4133 or 4134 utilized.

1. Check the microphone polarization voltage (if necessary, see page 23).
2. Connect the Condenser Microphone and its matching Cathode Follower as shown in Fig. 26.
3. The control knobs should be set as mentioned below:—
   "Input Switch": "Condenser Microphone"
   "Meter Range": "Ref."
   "Meter Switch": "Fast" "RMS"
   "Range Multiplier": "0 db × 1"
   "Function Selector": "Linear, 2—35000 c/s"
   Control knobs not mentioned can be in any position.
4. Allow a few minutes to warm up.
5. Turn the "Sensitivity-Condenser Microphone" potentiometer by means of a screwdriver until the meter pointer deflects to the red mark.

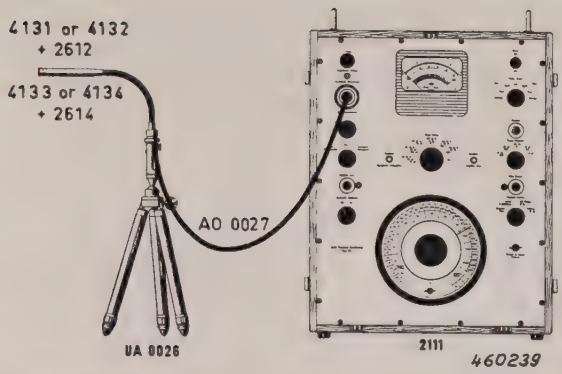


Fig. 26. Spectrometer set up for sound surveys or as Precision Sound Level Meter.

Microphone 4131 or 4132 utilized.

5. From the calibration chart of the Microphone employed, a correction factor "K" in db is taken.
6. Turn the "Sensitivity-Condenser Microphone" potentiometer by means of a screwdriver until the meter pointer deflects to the red mark + "K" db. If "K" is negative, it has to be subtracted from the value in db corresponding to the red mark.

II. Adjustment to the Sound Signal.

1. The Condenser Microphone should be exposed to the sound field.
2. "Meter Range" switch is turned counterclockwise until a suitable deflection is made on the instrument meter. If a convenient deflection on the meter cannot be obtained by using the "Meter Range" switch, the "Range Multiplier" switch may be set to a position with a higher sensitivity, refer page 21.

III. Measuring.

Microphone 4131 or 4132.

1. Set "Function Selector" to "⅓ Octave, 0 db" or "Octave, — 10 db" as desired.

Microphone 4133 or 4134.

1. Set "Function Selector" to "⅓ Octave, 0 db" or "Octave, — 10 db" as desired.

2. The absolute value of the Sound Pressure Level, or Sound Level (dependent upon the position of the Spectrometer filter switch), can now be read on the instrument meter by using the formula:—

The deflection in db on the indicating meter
+ the number of db S.L. indicated by "Meter Range"
+ the sum of numbers of db indicated by "Range Multiplier' and "Function Selector"

Example 1.
Deflection of the meter: 16 db
Position of "Meter Range": "60 db S.L."
Position of "Range Multiplier": "0 db, × 1"
Position of "Function Selector": "⅓ Octave, 0 db"
16 db + 60 db + 0 db + 0 db = 76 db S.P.L. or S.L.

Example 2.
Deflection of the meter: 10 db
Position of "Meter Range": "80 db S.L."
Position of "Range Multiplier": "— 10 db × 0.3"
Position of "Function Selector": "Octave, — 10 db"
10 db + 80 db — 10 db — 10 db = 70 db S.P.L. or S.L.

2. The absolute value of the Sound Pressure Level, or Sound Level (dependent upon the position of the Spectrometer filter switch), can now be read on the instrument meter by using the formula:—

The deflection in db on the indicating meter
+ the number of db S.L. indicated by "Meter Range"
+ the sum of numbers of db indicated by "Range Multiplier and "Function Selector"
+ the correction factor "K" db.

"K" is the correction factor for the Condenser Microphone, see Fig. 24, page 39.

Example 1.
Deflection of the meter: 2.7 db
Position of "Meter Range": "60 db S.L."
Position of "Range Multiplier": 0 db, × 1"
Position of "Function Selector": "⅓ Octave, 0 db"
Correction factor "K": 13.3 db
2.7 db + 60 db + 0 db + 0 db + 13.3 db = 76 db S.P.L. or S.L.

Example 2.
Deflection of the meter: 10 db
Position of "Meter Range": "80 db S.L."
Position of "Range Multiplier": "— 10 db × 0.3"
Position of "Function Selector": "Octave, — 10 db"
Correction factor "K": 13.3 db
10 db + 80 db — 10 db — 10 db + 13.3 db = 83.3 db S.P.L. or S.L.

Calibration or Checking of Measuring Arrangements for Sound Investigation by Means of a Calibrated Sound Source.

An easy way to calibrate or check a measuring arrangement is offered by the employment of our Pistonphone Type 4220 or Noise Source Type 4240.

1. Pistonphone.

The Pistonphone is a compact battery operated, easily portable device, designed for the calibration of microphones and measuring set-ups. Further information can be obtained from the respective manual or data sheet.

The procedure to calibrate or check a measuring arrangement which includes Spectrometer Type 2111 is:—

1. The Spectrometer control knobs should be positioned as follows:—

Microphone 4131 or 4132.

"Input Switch": "Condenser Microphone"
"Meter Range": "120 db S.L."
"Range Multiplier": "— 10 db × 0.3"
"Function Selector": "⅓ Octave, 0 db"
"Filter Switch": "Lin."
"Meter Switch": "RMS, Fast"

Microphone 4133 or 4134.

"Input Switch": "Condenser Microphone"
"Meter Range": "100 db S.L."
"Range Multiplier": "0 db, × 1"
"Function Selector": "⅓ Octave, 0 db"
"Filter Switch": "Lin."
"Meter Switch": "RMS, Fast"

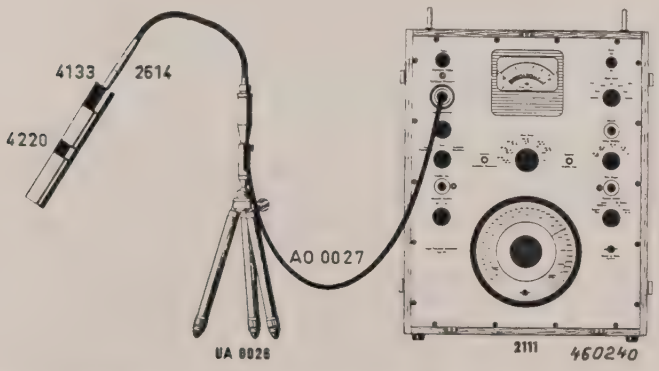


Fig. 27. Calibration of Spectrometer (Sound Level Meter) by Pistonphone Type 4220.

2. Place Pistonphone against Microphone Cartridge, (as in Fig. 27), switching on its motor.
3. The indicating meter on the Spectrometer should now deflect to:—

Microphone 4131 or 4132.

The value of S.P.L. given in db on the calibration chart for the

Microphone 4133 or 4134.

The value of S.P.L. given in db on the calibration chart for the Piston-

Microphone 4131 or 4132.

Pistonphone less 110 db.

Example:

The value of SPL given on the calibration chart: 124.2 db
The deflection of the indicating meter should then be:—
124.2 db — 110 db = 14.2 db

Microphone 4133 or 4134.

phone, less 100 db, and further, less "K".

"K" is the correction factor in db, *valid* for the Microphone in question.

Example:

The value of SPL given on the calibration chart: 124.2 db
The correction factor "K" of the Microphone 13.3 db
The deflection of the indicating meter should then be:—
124.2 db — 100 db — 13.3 db = 10.9 db

4. Possible deviation has to be corrected by means of the "Sensitivity — Condenser Microphone" accessible on the front of the Spectrometer.
5. When the Level Recorder Type 2305 is combined with the Spectrometer, the deflection of its stylus can readily be calibrated, or checked by means of the Pistonphone. The procedure being employed is the same as the one given above for the Spectrometer. The different control knobs of the Level Recorder being operated as outlined in "Automatic Recording of Voltage Analysis", paragraph A. II, page 32. For reading of level on the recording paper refer C. "Reading of absolute value from the spectrogram", page 41.

II. Noise Source.

The Noise Source is designed to give a quick check on measuring arrangements set for sound investigation. The Source is a cartridge in which steel balls generate the noise level. Further information being given in the manual or data sheet for this device.

1. The procedure for employing the apparatus is similar to that given for the Pistonphone, with the exception that the control knobs of the Spectrometer should now be set as follows:—

Microphone 4131 or 4132.

"Input Switch": "Condenser Microphone"
"Meter Range": "100 db S.L."
"Range Multiplier": "— 10 db × 0.3"
"Function Selector": "⅓ Octave, 0 db"
"Filter Switch": "Lin."
"Meter Switch": "RMS, Slow"

Microphone 4133 or 4134.

"Input Switch": "Condenser Microphone"
"Meter Range": "80 db S.L."
"Range Multiplier": "0 db, × 1"
"Function Selector": "⅓ Octave, 0 db"
"Filter Switch": "Lin."
"Meter Switch": "RMS, Slow"

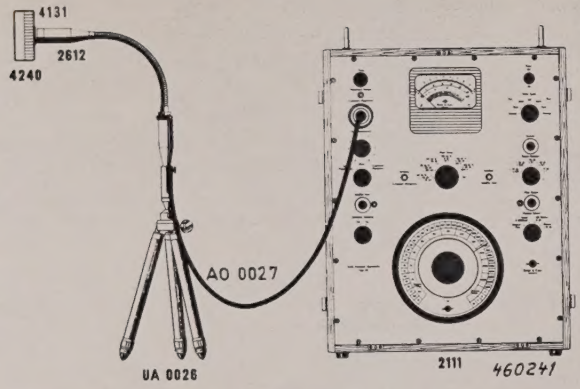


Fig. 28. Calibration of Spectrometer (Sound Level Meter) by Noise Source Type 4240.

2. The Noise Source is placed against the Microphone Cartridge (refer Fig. 28). The outer ring of the Noise Source housing should then be turned through 180°, whereby the noise is generated by the running of the steel balls.
3. The indicating meter of the Spectrometer should now deflect to:—

Microphone 4131 or 4132.
The value of S.P.L. written in db on the Source housing less 90 db.

Example:
Value of SPL given on the housing: 107 db

The indicating meter should then deflect to:—
107 — 90 = 17 db

Microphone 4133 or 4134.
The value of S.P.L. written in db on the Source housing less 80 db, and further, less "K".

"K" is the correction factor in db *valid* for the microphone in question.

Example:
Value of SPL given on the housing: 107 db
The correction factor "K" of the Microphone: 13.3 db
The indicating meter should then deflect to:—
107 — 80 — 13.3 = 13.7 db